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FEBRUARY, 1944
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The Journal of The Royal Aeronautical Society

which is incorporated The Institution of Aeronautical Engineers

Edited for the Council by Capt. J. LAURENCE PRITCHARD, Hon. Fellow

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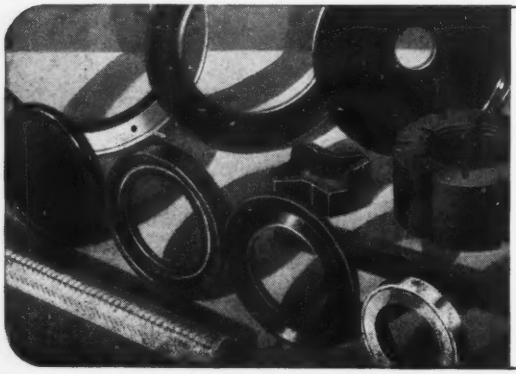

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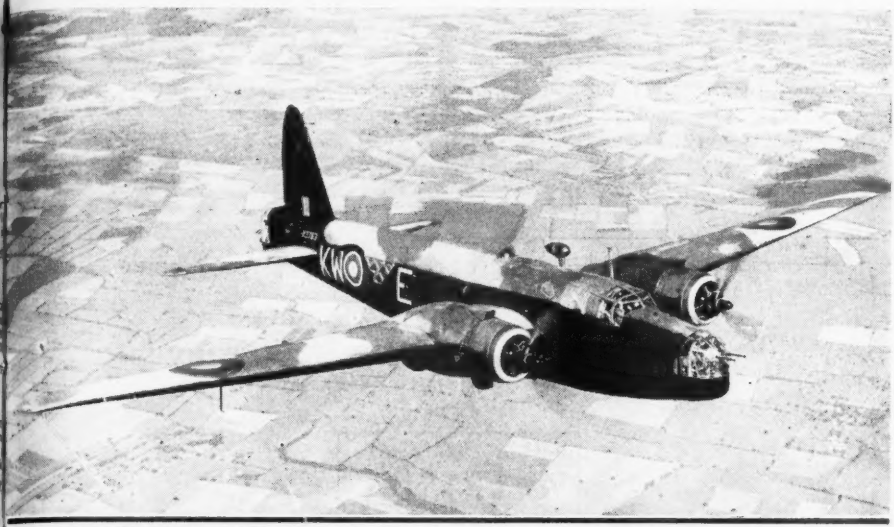

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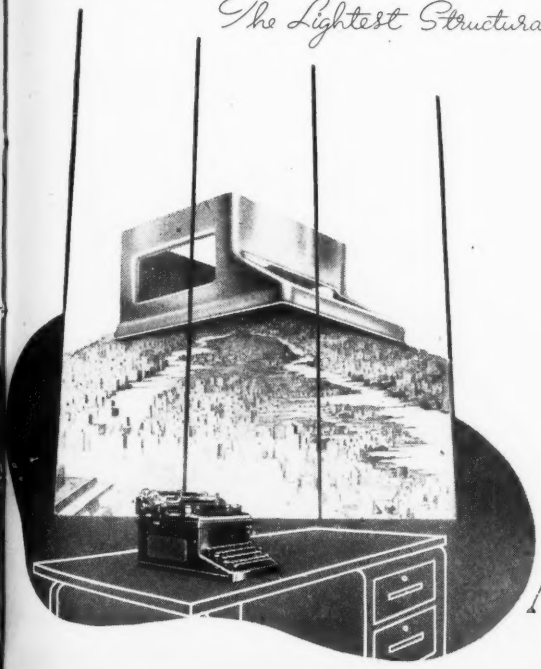

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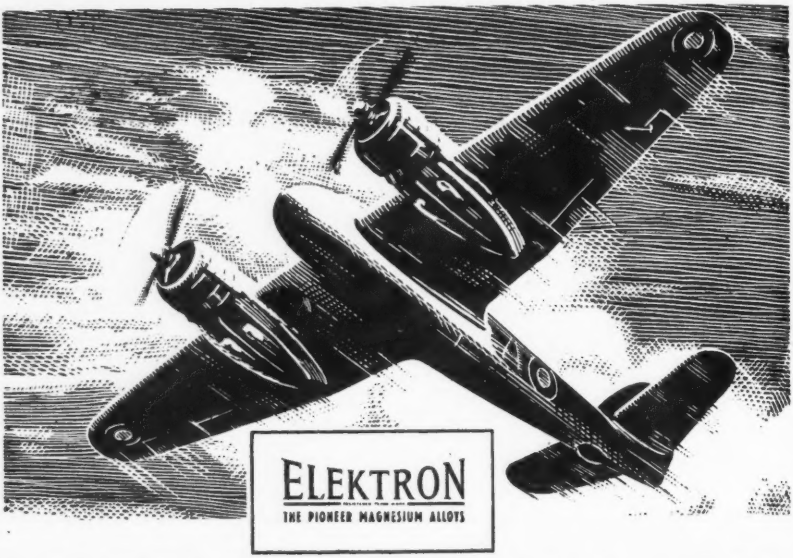

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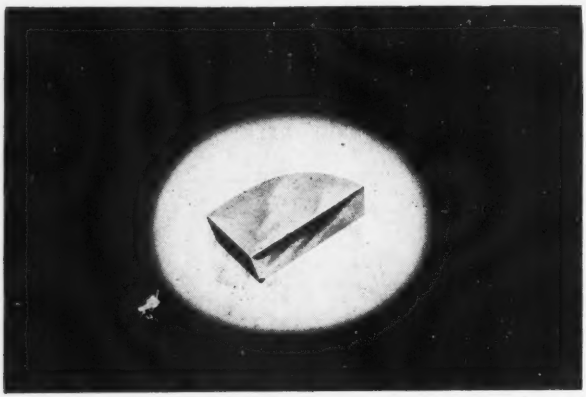

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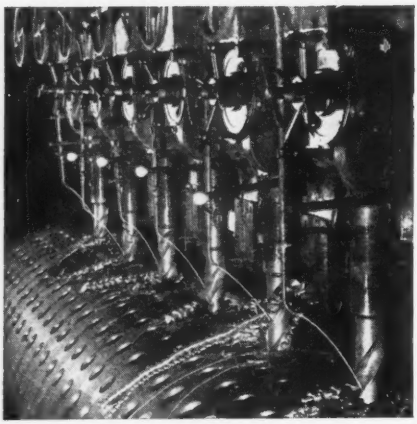

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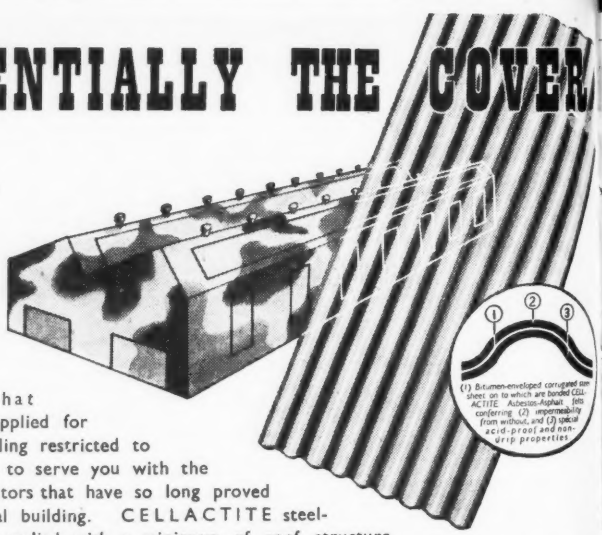
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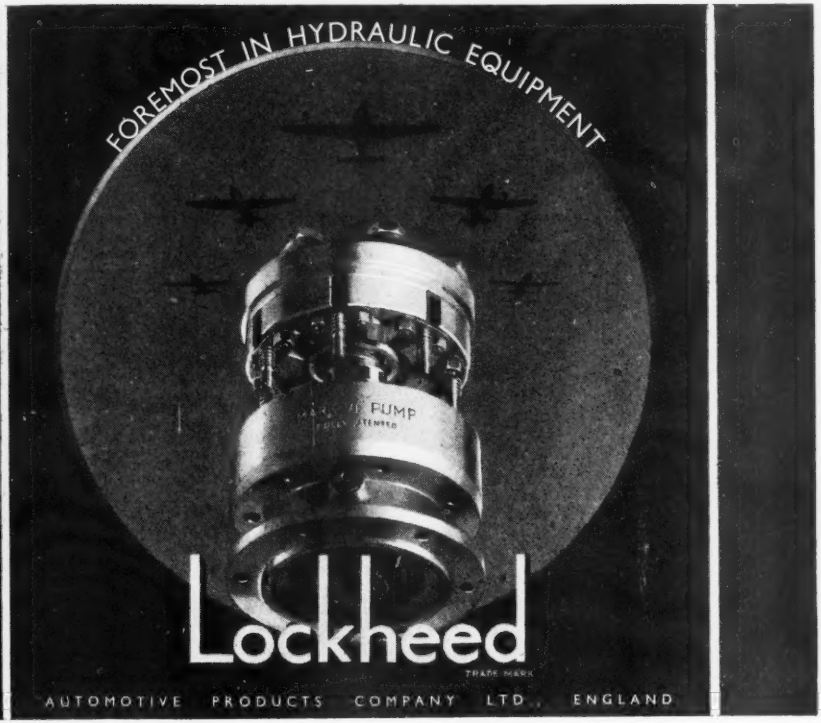

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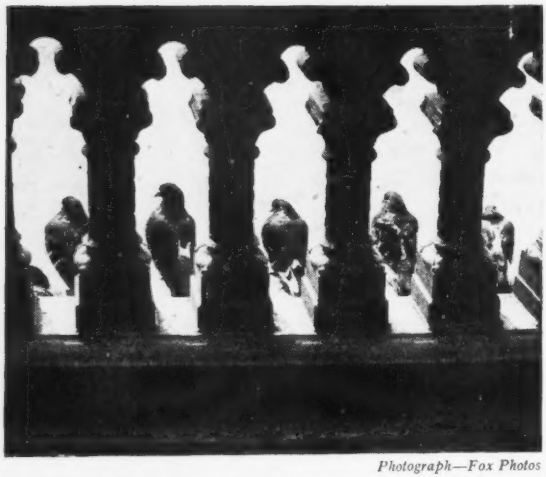

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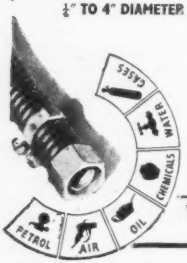

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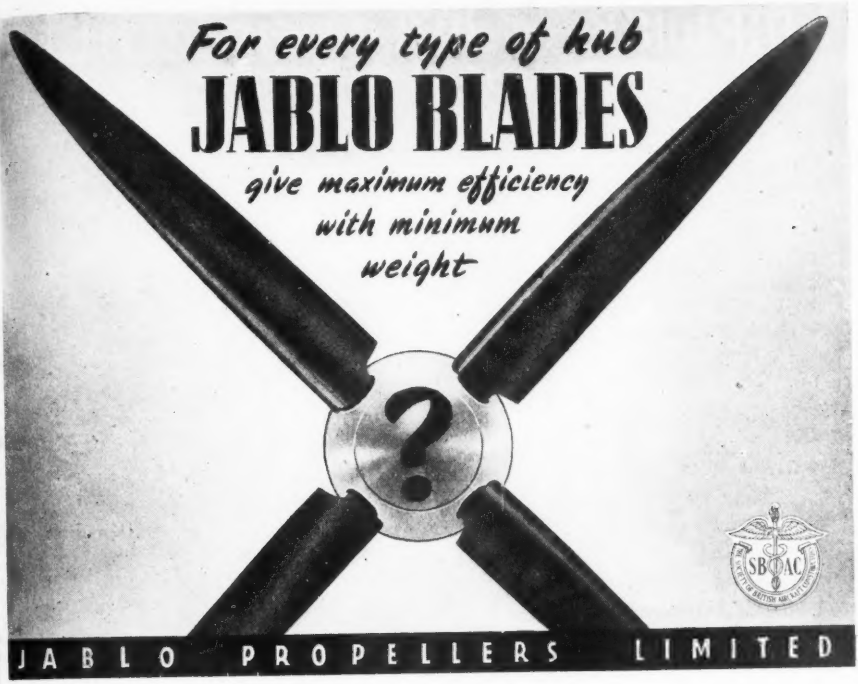
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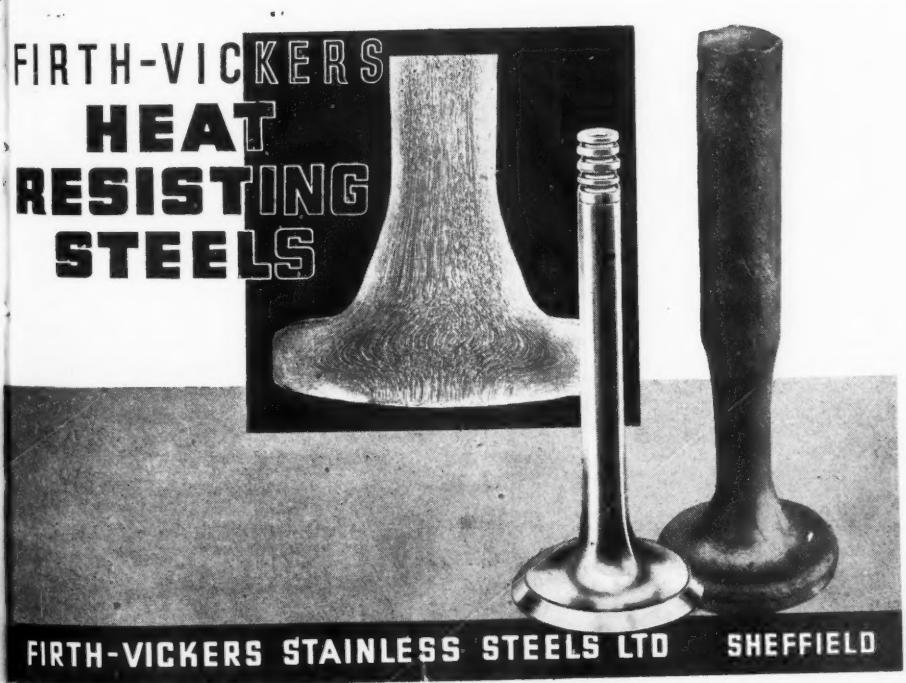
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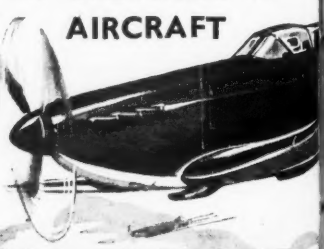

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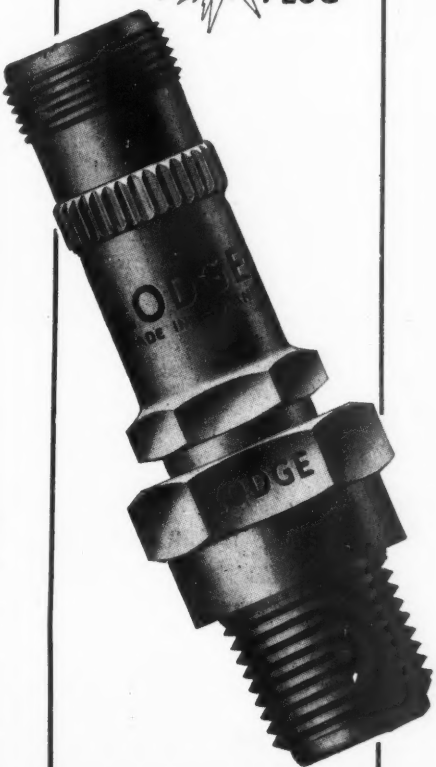

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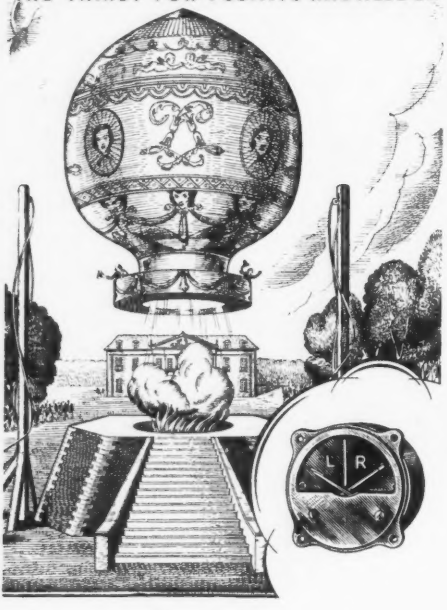

The Balloon

The brothers Montgolfier are credited with the invention of the "hot air" balloon, and their many experiments led eventually to a flight of one and a half miles, carried out in 1783. Later balloonists attempted to sustain flight by "taking the fire with them," and though many disasters occurred their perseverance added much to man's store of positive knowledge. A leading source of positive knowledge to the pilot of to-day is provided by Weston Aircraft Instruments, which so faithfully guide and inform him from take-off to landing.

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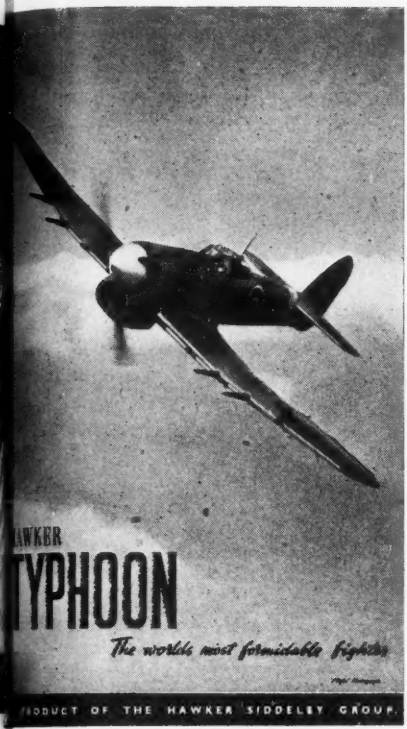

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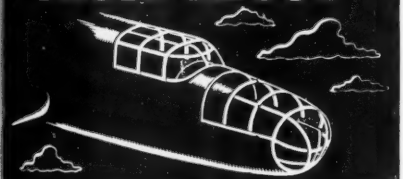

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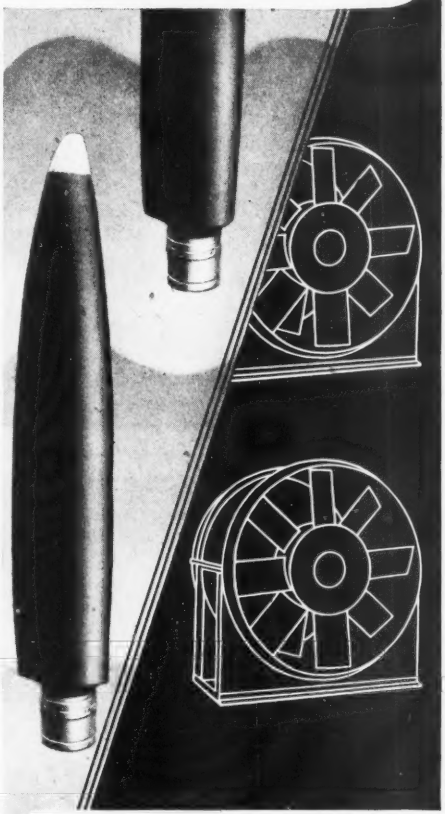

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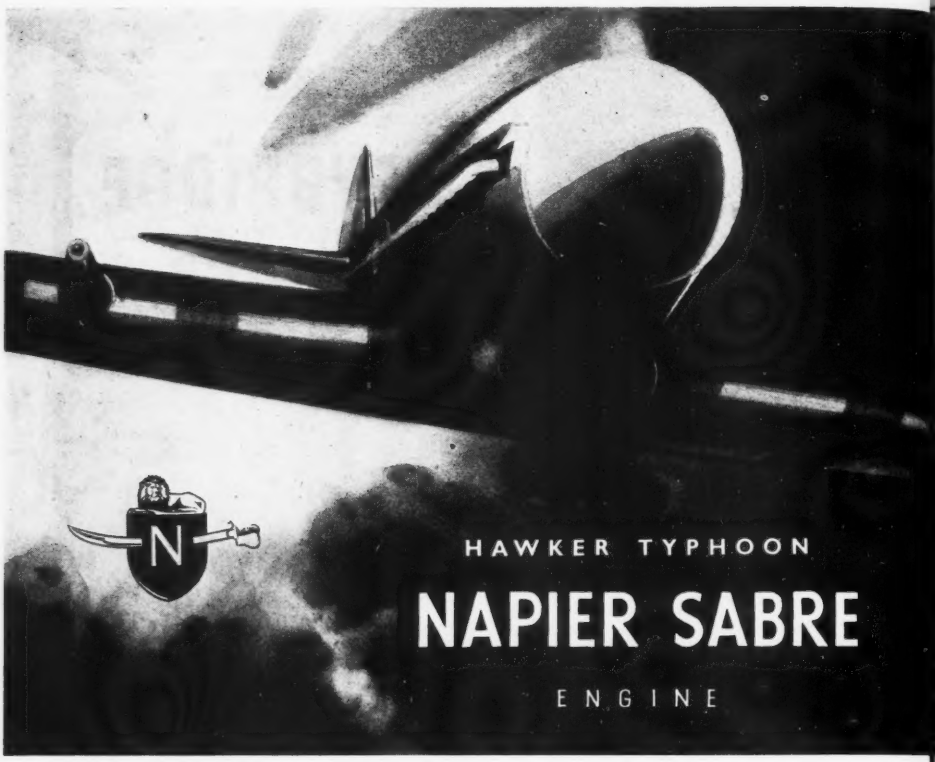
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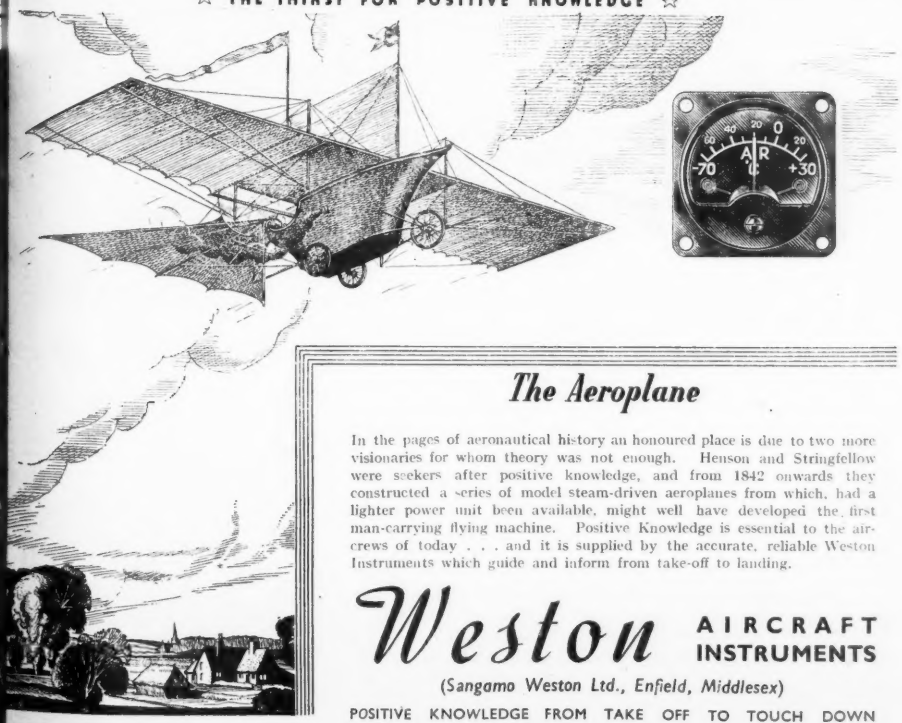

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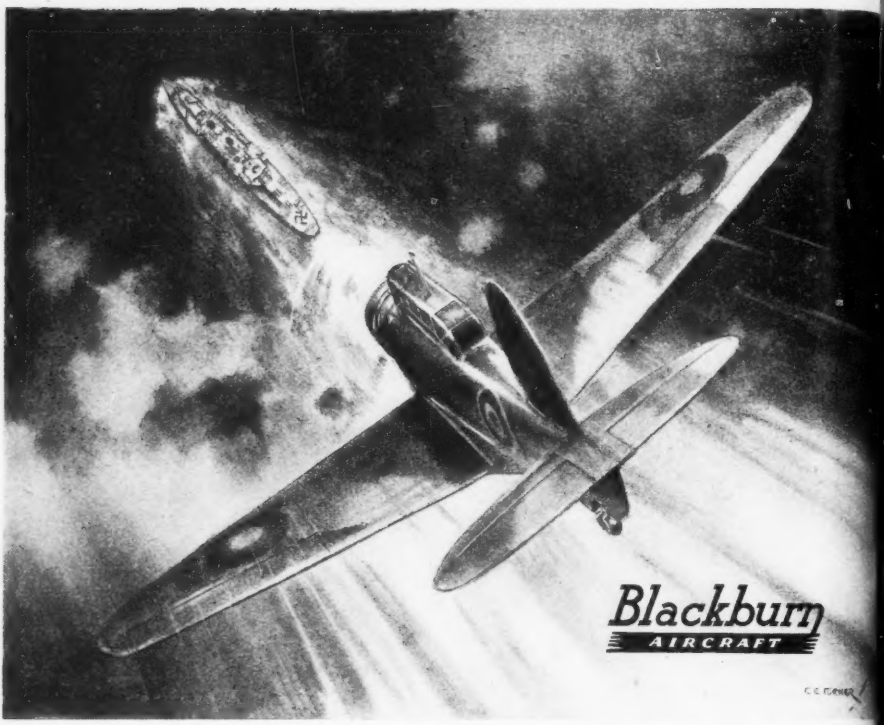

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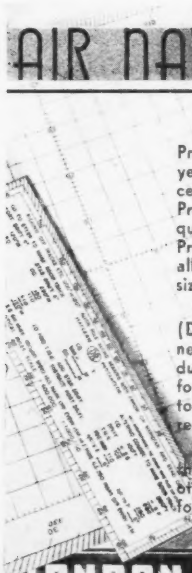

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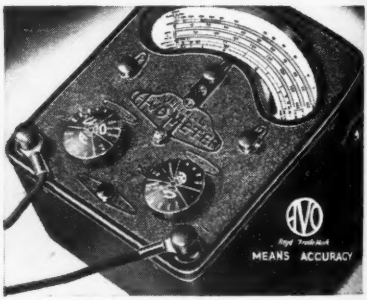

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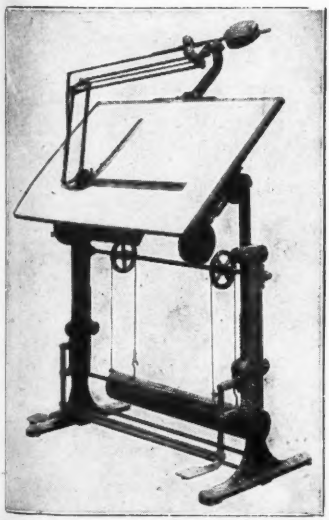

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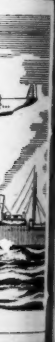

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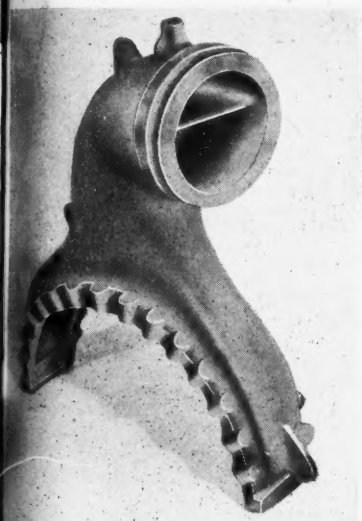

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MONTHLY NOTICES

FEBRUARY, 1944.

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C.B.E. (Military)—

N. E. Rowe, Fellow.
Frank Whittle, Associate Fellow.
Mr. H. M. Woodhams, Associate Fellow.

O.B.E.—

Wing Commander A. C. Kermode, B.A., Fellow.

Society of British Aircraft Constructors' Scholarships.

The S.B.A.C. Scholarships are open to British subjects between the ages of 16 and 18 on the 1st September in the year of the award. They are designed for the assistance of young men who are unable, for financial reasons, to take up a course of education fitting them to become aircraft engineers. The general administration is carried out by the Royal Aeronautical Society and applications for entry forms should be addressed to 4, Hamilton Place, W.1. Entries for 1944 close on February 28th, 1944.

Lectures.

The following lectures have been arranged. They will be delivered at 5.30 p.m. in the Lecture Hall of the Institution of Mechanical Engineers, by kind permission of the Council of the Institution:—

February 10th, 1944.—"Flight Testing Methods," by Mr. E. T. Jones, M.Eng., A.F.R.Ae.S.

February 24th, 1944.—"Structural Features of German Aircraft," by Mr. D. M. A. Leggett, Ph.D., A.F.R.Ae.S., and Mr. H. Davison.

March 9th, 1944.—"Aerodynamic Features of German Aircraft," by Mr. M. B. Morgan, M.A., A.F.R.Ae.S., and Mr. R. Smelt, B.A.

Graduates' and Students' Section.

The following lectures have been arranged by the Graduates' and Students' Section. They will be delivered in the Library, at 4, Hamilton Place, W.1, at 7.30 p.m.

Wednesday, April 19th.—Mr. A. J. Penn on "The Design and Operation of Superchargers."

Thursday, May 11th.—Mr. J. A. Churchill on "Power Plant Installation and Design."

Graduates and Students are also invited by the Graduates' Branch of the Institution of Automobile Engineers to the following meetings:—

Sunday, February 13th.—Informal Talk by Mr. John Bolster on "How to Make Your Own Motor Car."

Sunday, March 12th.—Paper by Mr. C. L. James on "Torsion Bar Springs for Automobile Suspension."

Sunday, April 16th.—Informal Talk by C. Kimber on "The Sports Car—Its Past and Future."

All the above will be held at 3.0 p.m. at the Institution of Automobile Engineers, 12, Hobart Place, S.W.1.

Graduates' and Students' Visits.

The delay in advising Graduates and Students, who have intimated their desire to attend the De Havilland Assembly Plant, is due to spread over of visits to one per month until May.

Branch Lectures.

The following Lectures have been arranged before the Luton Branch:—

Wednesday, 9th February, 1944, at 7.15 p.m.—Lecture on "Compressibility," by Dr. W. F. Hilton, B.Sc., D.I.C., A.F.R.Ae.S., of the Aerodynamics Dept., National Physical Laboratory, Teddington.

Wednesday, 1st March, 1944, at 7.15 p.m.—Lecture on "Superchargers," by A. J. Penn, A.M.I.Mech.E., Supercharger Development Engineer, D. Napier and Son, Ltd., Acton.

Wednesday, 5th April, 1944, at 7.15 p.m.—Lecture on "Air Transport," by Dr. Roxbee Cox, B.Sc., D.I.C., F.R.Ae.S., Vice-President of the Royal Aeronautical Society.

Council Election.

Attention is drawn to the following Rules for election of Council. Nominations for Council should be received by March 3rd, 1944. Nomination forms may be obtained from the Secretary. Attention is drawn to possible delays in the post at the present time.

RULE 17.—One half of the Council (excluding the President and the immediate Past-President if a Member of Council) shall retire annually. The members who shall retire shall be those longest in office, except as provided in Rule 77. Retiring members of Council who have served for two terms in succession (four years) shall not be eligible for re-election until the next annual election, when they will be eligible.

RULE 72.—The composition of the Council shall be as follows:—

(*a*) Not less than sixteen shall be elected from the technical or scientific grades of the R.Ae.S., that is to say, from among the Fellows, Associate Fellows, Associates and Graduates.

(*b*) Of these sixteen, four at least shall be Fellows.

RULE 73.—Nominations of candidates for election to the Council must be received by the Secretary not less than twenty-one days before the Annual General Meeting, with an intimation in writing by the Candidates that they are willing to serve. Nominations must be signed by one supporter and two seconders, who must be each entitled to vote in the R.Ae.S.

Elections.

The following members were elected at a recent meeting of Council:—

Associate Fellows.—George Douglas Chapman, Robert Charles Cox (from Associate), Sidney Henry James Freemantle (from Graduate), Cecil Walter George, Charles Leslie Hinings, Harry Michael Keegan, Sidney Kirkby (from Graduate), Lionel Edward Leavy, Arthur Francis McKeown, George Wishart Nicholas (from Graduate), Cyril George Pullin, Rowland Towers (from Graduate), Stanislaw Wernicki, Patrick Huia Wilkinson (from Graduate), John Arthur Charles Williams (from Graduate).

Associates.—George Robert Allison, Cyril Arthur Baker, Joseph Baker, Cyrus William Bennett, Harry Bentley (from Student), Douglas Leonard Bisgood, Maurice Booth, Arthur Valentine Cleaver (from Student), Arthur Ernest Fishlocke, James Joseph Vincent Flavin, Harold Howard Gott, Claude Douglas Hurst, Cameron Frederick Mervyn Jones (from Student), Raymond Alan Kellow, George Bernard McEvoy, William Brydon Fraser Mackay, Philip Idwal Morgan, Vincent John Van der Merwe, Douglas Cecil Hampton Owen, Reginald Edgar Packer, Norman Kenneth Parry-Billings, Robert Henry Peacock, Edwin Charles Witter Pearce (from Student), Sidney John Peskett, Clifford Frederick Upham, James Webber, Walter Richard Wells, William Charles Maxted Whittle, David Ernest Williams.

Graduates.—Peter Kenneth Cowan (from Student), Thomas Kenneth Garrett (from Student), Sidney Clifford Bernard Hailey, John Humphries, William Aylwin Jones, Richard Norman Kemp, Anthony Arthur Rose, Austin Geoffrey Smith, Robert Neville Stott, Joseph Arthur Tickell, Vivian Humphrey Wickham, Charles Frank Watkinson (from Student), John Bennett Witchell, Donald Arthur Sydney Woodbridge.

Students.—Robert Henry Watson Annenberg, Ronald George Bailey, Walter Gordon Bradfield, Raymond Montrose Brown, Leonard James Lewis Davies, Douglas Frank Denny, Peter Ebershardt, Allan Henry Griffiths, Peter George Griffiths, Ernest Ralph Hall, Digby Kenneth Harris, Robert Alan Jeffs, Keith Kirkus, Jack Harry London, David Howitt Marshall, Peter Mitchell, Ian Richard Muir, Ralph Oakes, Arthur Loftus Paddington, Colin Richard Kirwan Peal, Charles Erling Gjertsen Payne, J. E. Rapson, James George Preston-Holt Risehalgh, Gordon Rosenthal, Patrick James Sibley, Joseph Stevens, Frederick Arthur Swan, Bruce Maynard Taylor, Francis Todd, Rex Waller.

Companions.—Guy Alexander Parker Hunt (from Student).

Monthly Notices.

The Secretary very much regrets that members to whom the Monthly Notices were sent last month were asked for a surcharge on the postage. The method of sending these circulars out was approved by the postal authorities in the first place and no difficulty has been experienced in the past. The matter is being taken up with the postal authorities and it is hoped members will accept this apology and will not be troubled again in this way.

Annual Subscriptions of Members.

Members are reminded that their 1944 subscriptions became due on 1st January, 1944.

The Council are very grateful to all those members who have offered to forego their Journals for the duration of the war. The same reductions will be made to the 1944 subscriptions of these members as applied to the 1943 subscriptions. Subscriptions of Fellows, Associate Fellows, Graduates, Companions and Founder Members, who have given up their Journals will therefore be reduced by 10s. 6d. Associates will receive the reduction already laid down in the Rules and the low subscription at present paid by Students does not permit any reduction to be made.

The following will be the rates for 1944 therefore:—

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Associates	2 2 0	1 1 0	2 2 0	1 1 0
Graduates (age 21-25) ...	2 2 0	1 11 6	2 2 0	1 11 6
,, (age 26-28) ...	2 12 6	2 2 0	2 12 6	2 2 0
Students	1 1 0	1 1 0	1 1 0	1 1 0
Companions	2 2 0	1 11 6	2 2 0	1 11 6

Those members who forego their Journal are kept informed of the activities of the Society by having the Monthly Notices sent to them.

Journal Binding Costs.

Owing to increased costs, the prices of binding of all Journals will be as follows:—

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1942 ,, ...	9 0
1941 ,, (excluding Library Catalogue) ...	9 0
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The Secretary, Royal Aeronautical Society,

4, Hamilton Place, London, W.1.

Duplicate Magazines.

The Secretary of the Institute of the Aeronautical Sciences would very much appreciate it if a member of the Society could supply the Institute with any of the following, which were lost in transit, and are required to complete their bound file volumes. There are no copies available at the publishers.

Flight, April 8th, 1943.
Aircraft Production, Vol. 5, No. 53 (1943).
Aircraft Engineering, February, 1943.

Approximate Solution for Tapered Pin-Ended Struts (Correction).

In equation (21) the bracket sign immediately after the term $2B/\pi^2$ in the numerator on the R.H.S. should be deleted. As the expression stands at the moment there is some confusion as to the sign of the last term, 0.0736 C.

In its correct form, the equation should read

$$\frac{a}{e}=\beta\,.\,\frac{\left\{\left(\frac{2}{\pi}\right)\left(\frac{\beta}{\pi^2}+1\right)-\left(\frac{2A}{\pi}+\frac{2B}{\pi^2}+0.0736\,C\right)\right\}}{\left\{\pi^2\left(\frac{A}{2}+0.1756\,B+0.067\,C\right)-\frac{\beta}{2}\right\}} \qquad (21)$$

Additions to Library.

Pamphlets in italics with location reference following in brackets.
Books marked * may not be taken out on loan.

B.a.308.—The Red Air Force. John Stroud. Pilot Press, Ltd. 1943. 5/-.

B.c.64.—*Men-Birds Soar on Boiling Air. Fredk. G. Vosburgh.* (*Article in "National Geographic Magazine," July*, 1938.) (Y.10.a.10.)

B.c.65.—*Air Trailers—Post-War Freight Cars of the Skyways. F./O. R. Parkinson.* (*Photostat from article in "U.S. Air Services," Oct.*, 1943.) (Y.10.a.11.)

B.e.41.—The Design and Construction of Flying Model Aircraft. (3rd Ed.) D. A. Russell. Aircraft Technical Publications, Ltd. 1943. 10/6.

B.f.88.—*Adventures with Birds of Prey. F. and J. Craighead. National Geographic Magazine.* ? 1936. (Y.7.b.4b.)

*B.g.131-133.—Aircraft of the Fighting Powers. H. J. Cooper and O. G. Thetford. Vol. II (1942); Vol. III (1942); Vol. IV (1943). Harborough Publishing Co. (Aircraft Technical Publications, Ltd.). Price 21/- each volume.

*BB.d.33.—*Quick Release Fasteners on German Aircraft. M.A.P. Official Description* (*Stencil*), *26/11/43, and Correction, 6/12/43.* (Y.3.iii.25.)

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J. LAURENCE PRITCHARD, *Secretary and Editor.*

STRESS CONCENTRATION IN COLD-RIVETED JOINTS UNDER LOAD.*

M. KOENIG.

Schweizer Archiv., Vol. 3, No. 2, Feb., 1937, pp. 41-46.

Translated by L. J. GOODLET.

SUMMARY.

Investigations have shown that with the addition of Kirsch's supplementary stresses to the elastic expansion and rivet side-thrust, there is a liability to dangerous stress concentration at the edge of the rivet hole. The influence of these edge stresses on the adjacent hole(s) and the plate margin, also requires investigation.

However, since in spite of this disadvantage, riveting is in practice found to be superior to welding, it is evident that the edge stresses must be effectively neutralised by combined elastic and permanent deformation of the material around the hole. At the same time, the unavoidable weakening of plate and hole edges by hair cracks, etc., makes it advisable to pay special attention to the following points :—

1. The initial stresses, in the plates to be joined, should be kept as low as possible.

2. Rivet holes should be accurate and cleanly finished.

3. Rivets should not be too closely spaced.

4. The plate margin should be wide enough to avoid risk of breakdown through stress concentration due to hair-cracks or small notches.

5. The edges of the plates and rivet holes should be reamed to remove hair cracks and local crumbling.

1. INTRODUCTION.

The use of high duty, light metal alloys has recently been extended far beyond their original sphere of aeronautical engineering, and they have been successfully applied to the construction of both road and rail vehicles.

For such heavy substantial structural components, riveting has remained the preferred method of connection; the consequent increase in the scantlings of plates and rivets involved, now makes it necessary to differentiate the applicable riveting technique from the standard practice in the assembly and riveting of structural steelwork. This has already been done in a number of theoretical and practical studies, for details of which the reader is referred to the standard handbooks and literature on aluminium.[†]

Riveting in light alloys differs essentially from steel riveting in that the load is not transmitted by uniform shrinkage of a hot-clenched rivet and consequent compression of the joint, but by the side-thrust (bearing pressure) of the cold-clenched rivet in the hole. This consideration neglects, however, the radial and

* Printed by permission of the Ministry of Aircraft Production (R.T.P.).

† v. Zeerleder: AIAG Blätter.

tangential stresses set up in the plates by the elastic lateral expansion of the hole, which completely upset the normal calculated stress distribution in the joint.

A further point practically disregarded by the analyses given in current literature on the subject, but which may operate owing to the absence of any compressive effect of the cold-clenched rivet, is the influence of the initial stresses in the plates, on the stress distribution at the rivet hole.*

These stress-raising factors, capable of giving rise to dangerous stress-concentrations are analysed quantitatively on an elementary example of a single-row riveted joint, as a groundwork for the development of a more complete testing technique to furnish the ultimately correct values. In this connection, photo-electric tests should be capable of giving a good insight into these complicated stress conditions.

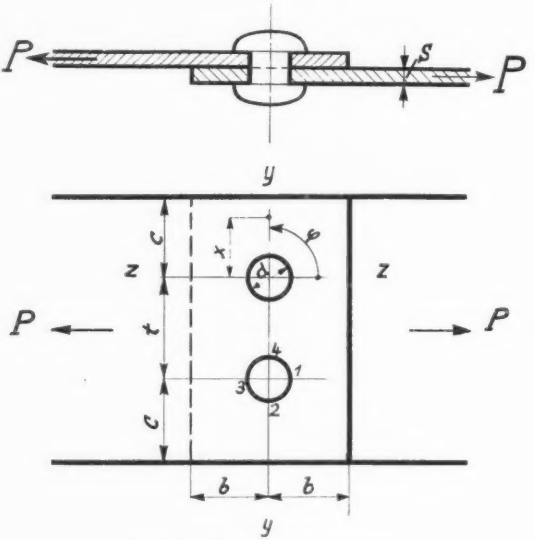

Abb. 1 Einschnittige Nietung

FIG. 1.
Single-row riveting.

The present investigation was conducted with two different rivet spacings, in order to demonstrate the manner in which with decreasing pitch, the stresses at the edge of the rivet hole are affected by the elastic expansion of an adjacent hole, and the corresponding necessity of adjusting the spacing of the rivet from the edge of the plate.

The *elastic expansion* of the hole by a cold-driven rivet has been particularly investigated and measured by the research workers of the Aluminium-Industrie A.-G. Neuhausen. It sets up tangential and radial stresses in the plate, which decrease with the square of the distance from the rivet centre. These stresses can be calculated with satisfactory approximation by the theory of shrinkage, on the assumption of an over-dimensioned rivet driven into a hot and consequently expanded hole.

* " Aluminium in Transportwesen " (Aluminium in Transport Engineering) K-Circular No. 5, June, 1936.

Radial stress :—

$$\sigma_r = -p_A (r^2/x^2).$$

Tangential stress :—

$$\sigma_t = +p_A (r^2/x^2).$$

Shrinkage stress :—

$$p_A = \tfrac{1}{2} E\Delta/r,$$

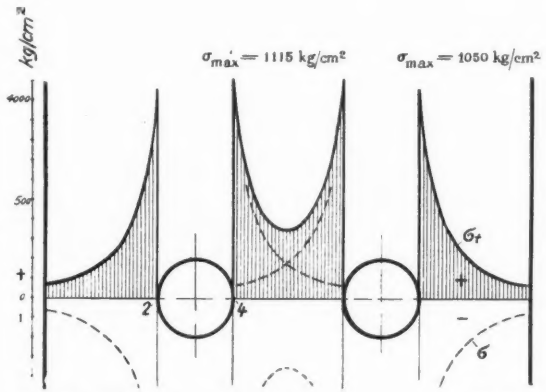

Abb. 2. Elastische Lochaufweitung. $1\frac{1}{2}\,‰$ ($t = 2{,}5\,d$).

FIG. 2.
Elastic expansion.

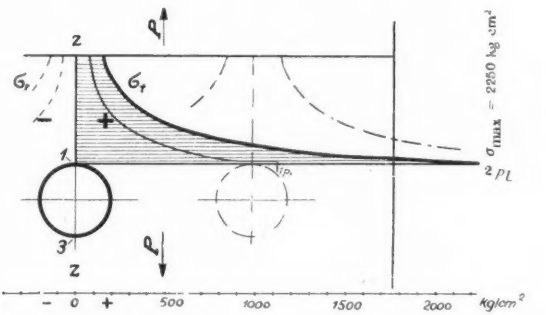

Abb. 3. Lochlaibung ($t = 2{,}5\,d$).

FIG. 3.
Rivet bearing pressure (side thrust).

where r = radius of rivet hole, cm.
x = distance of stress point from rivet centre, cm.
E = modulus of elasticity (=700,000), kg./cm.².
Δ = elastic expansion, cm.
p_A = unit shrinkage stress, kg./cm.².

The elastic expansion was assumed to be 0.15 per cent. in excess of the permanent plastic deformation.

The stresses at and near the edge of a hole resulting from the *initial stresses* in the plate have been determined by *Kirsch's* method;* although the assumption of a symmetrically-equal tensile stresses is not entirely applicable owing to the concentrated transmission of the load at the rivet hole. Hence:—

Tangential stress:—

$$\sigma_t = \tfrac{1}{2} \cdot p \left(1 + \frac{r^2}{x^2}\right) - \tfrac{1}{2} \cdot p \left(1 + \frac{3 \cdot r^4}{x^4}\right) \cos 2\phi$$

Radial stress:—

$$\sigma_r = \tfrac{1}{2} \cdot p \left(1 - \frac{r^2}{x^2}\right) + \tfrac{1}{2} \cdot p \left(1 - \frac{r^2}{x^2}\right) \left(1 - \frac{3r^2}{x^2}\right) \cos 2\phi$$

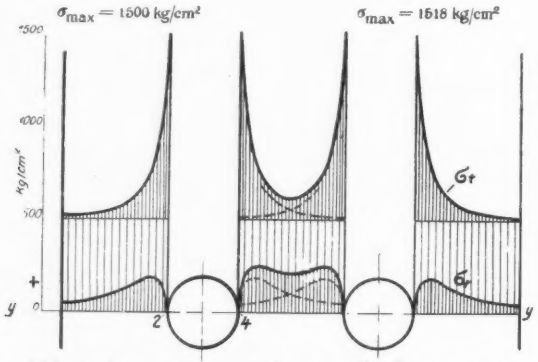

Abb. 4. Aussere Beanspruchung im Blech ($t = 2.5\ d$).

FIG. 4.

Initial plate stress.

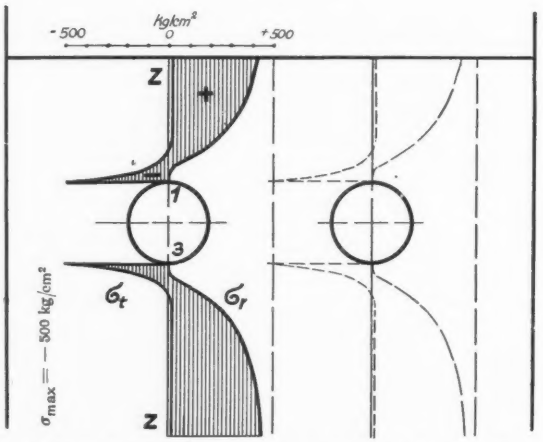

Abb. 5. Äussere Beanspruchung im Blech ($t = 2{,}5\ d$).

FIG. 5.

Initial plate stress.

* See Appendix to present translation.

where p = initial load on plate, kg./cm.^{2}.

x = distance of stress point from rivet centre, cm.

r = radius of rivet hole, cm.

ϕ = angle made by the direction of force with the line joining the stress point and rivet centre.

The initial load was assumed at 500 kg./cm.^{2}.

The development and numerical value of the *side thrust* of the rivet in the hole has been based on the assumptions indicated in the accompanying drawing, since the further variation caused by the bending moments in the rivet shank proceeding from the effect of the transmitted load is practically indeterminable. These stresses will also decrease with the square of the distance from the rivet centre.

These three principal stress components—side-thrust, initial load, elastic expansion—can finally be summated algebraically in a total stress peak, the value of which may be surprisingly high. The following analysis is directed to discovering the order of magnitude of such stress concentrations, on the simplifying assumptions indicated by Fig. 1.

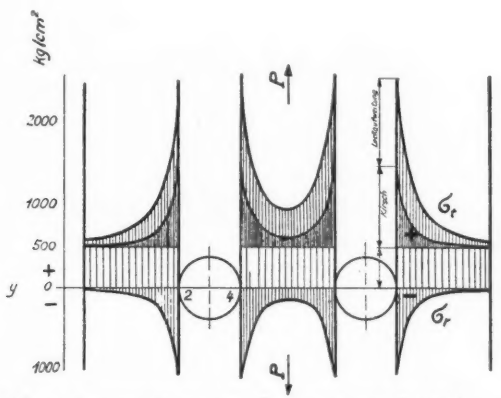

Abb. 6. Summenkurve σ_t und σ_r quer zur Kraftrichtung ($t = 2{,}5\,d$).

FIG. 6.

Curve of total stress transversely to direction of force.

II. CLOSELY-SPACED RIVETS (PITCH $t = 2.5\ d$).

Conditions were analysed at four points on the periphery of the hole, Nos. 1, 2, 3, 4 with a rivet spacing of $t = 2.5\ d$ and a plate thickness of $s = 0.5$ cm. Hence:—

Rivet diameter $d = 1.3$ cm.

$b = 2.6$ cm.

$c = 2.6$ cm.

The initial stress in the plate was assumed constant at:—

$$p = 500 \text{ kg./cm.}^2.$$

The corresponding equations of stress are:—

$$\sigma_t = + p_A\,(r^2/x^2)$$

$$\sigma_r = - p_A\,(r^2/x^2)$$

At the edge of the hole, since $x = r$, $\sigma = 1{,}050$ kg./cm.^{2}, where σ_t = tensile and σ_r = compressive stress. Disregarding any influence of a neighbouring hole, the stresses along the edge of the hole are uniform. The actual plotted curve, however, includes the influence of a neighbouring hole; at Point 4, for instance, it amounts to 65 kg./cm.^{2}, so that the total stress there is 1,115 kg./cm.^{2}.

With the selected spacing of $c = 2d$ from the plate edge to the rivet centres, the stress at the plate edge is 65 kg./cm.^{2}.

SIDE THRUST (RIVET BEARING PRESSURE).

In the direction of force, Point 1, section "$z - z$."

Approximately:—

$$\sigma = \pm p_L \, (r^2/x^2)$$

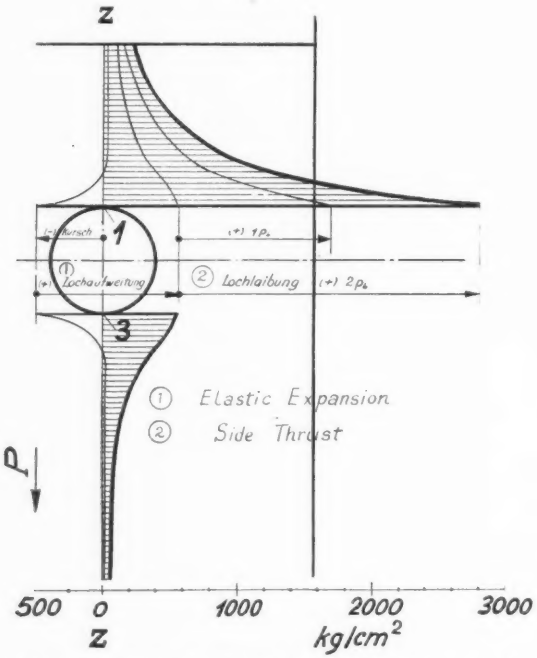

Abb. 7a. Summenkurve σ_t in Kraftrichtung ($t = 2{,}5\,d$).

FIG. 7*a*.

Curve of total stress in direction of force.

The side thrust acts conformally only in the one half of the rivet hole. The mean stress is in the actual case:—

$$p_L = P/(2 \,.\, d \,.\, s) = 1{,}125 \text{ kg./cm.}^2$$

this value also decreasing with the square of the distance from the rivet centre. Here again the tensile stress is represented by σ_t and the compressive stress by σ_r; hence, at the edge of the hole:—

$$\sigma_t = +1{,}125 \text{ kg./cm.}^2$$
$$\sigma_r = -1{,}125 \text{ kg./cm.}^2$$

Tests have shown that the side thrust on the edge of the hole can be as much as twice or two and a half times the value of the mean stress p_L. In the present example, consequently, curves have been plotted both for the simple and the double mean stress p_L.

For the extreme Point 1, the tangential tensile stress thus becomes 1,125 and 2,250 kg./cm.^{2} respectively, the radial compressive stress being of the same value. At the edge of the plate ($b = 2d$) the residual stress due to side thrust will be 75 and 150 kg./cm.^{2} respectively.

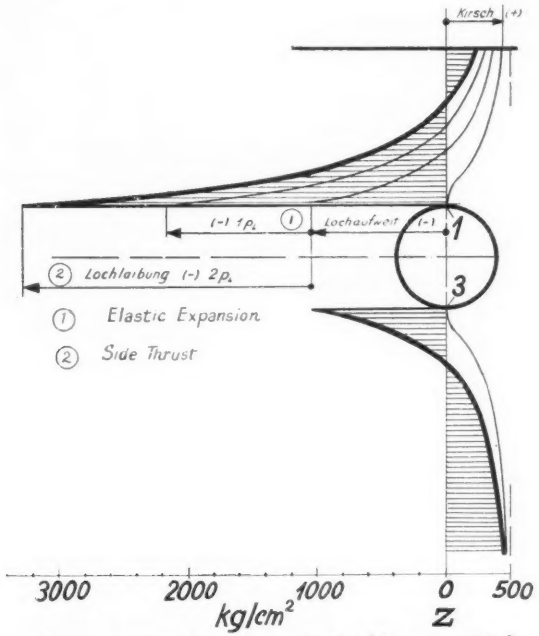

Abb. 7b. Summenkurve σ_r in Kraftrichtung ($t = 2.5\,d$).

FIG. 7*b*.

Curve of total stress in direction of force.

INITIAL STRESS IN THE PLATE.

(*a*) *Transversely to the direction of force*:—Points 2 and 4, cross-section "$y - y$."

The initial stresses have been calculated, as already explained, by Kirsch's equations.

Since $\cos 2\phi$ is unity for both Points 2 and 4, the stress development at these points is identical.

At the edge of the hole:—

$$\sigma_t = 1{,}500 \text{ kg./cm.}^2, \quad \sigma_r = 0.$$

The tangential stress at the edge of the hole is three times the mean stress, but thereafter decreases abruptly, and asymptotically approaches the initial plate stress of 500 kg./cm.^{2}. At the edge of the plate the residual overstress is only 18 kg./cm.^{2}. Here also the influence of a neighbouring hole is clearly apparent. The radial stress, which is zero at the edge, first rises to about 190 kg./cm.^{2}, and then also approaches the zero line asymptotically.

(*b*) *In the direction of force*:—Points 1 and 3, cross-section "$z-z$."

These stresses have also been determined by *Kirsch's* method. At the edge of the hole the tangential compressive stress in 500 kg./cm.^{2}; this, however, rapidly decreases, crosses the zero line and assumes a small positive value, and finally approaches zero at infinity.

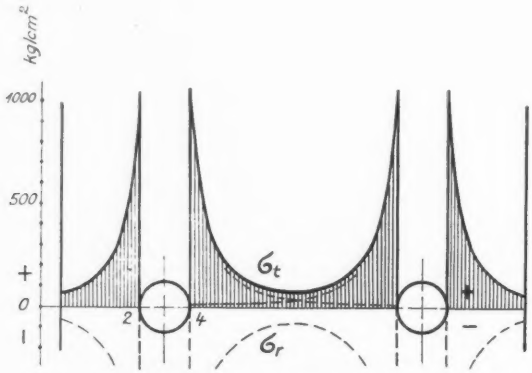

Abb. 8. Elastische Lochaufweitung $1\frac{1}{2}\,‰$ ($t = 5\,d$).

FIG. 8.

Elastic expansion.

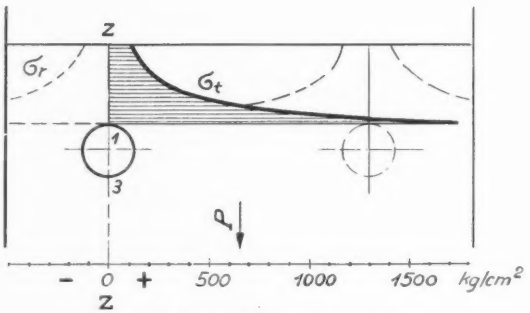

Abb. 9. Lochlaibung ($t = 5\,d$)

FIG. 9.

Rivet bearing pressure (side thrust).

The radial stress is zero at the edge of the hole and rises to 500 kg./cm.^{2} at infinity.

It is now possible to set up the curves for the algebraic total stress.

THE ALGEBRAIC TOTAL STRESS CURVES.

(*a*) *Transversely to the direction of force*:—Points 2 and 4, cross-section "$y-y$."

At Points 2 and 4 the side thrust is zero, the cumulative stresses are, therefore, only the elastic expansion and the initial stress in the plate, as well as the additional stresses determined by *Kirsch*.

As shown by the plotted curve, the resulting peak stresses are quite considerable. The mutual influence of neighbouring holes in closely-spaced riveting is also quite obvious; between two holes, *e.g.*, in the actual case of a pitch of $t=2.5\,d$, the stress is almost double the mean stress in the plate. The peak stress at the edge of the hole occurs at Point 4, and attains a value of 2,633 kg./cm.^{2}.

(*b*) *In the direction of force*:—Points 1 and 3, cross-section "$z-z$."

At Point 1 all three component stresses are cumulative; at Point 3 the side-thrust is inoperative. Fig. 7*a* shows the tangential stresses at Point 1. The initial plate stresses calculated according to *Kirsch*, are marked "Kirsch" on the diagram; these have a damping effect on the peak stress, the maximum value at Point 1 being $\sigma_t=1,675$ kg./cm.^{2}, with simple side-thrust, the peak tangential stress with doubled side-thrust being 2,800 kg./cm.^{2}. The radial stress develops similarly, as shown in Fig. 7*b*.

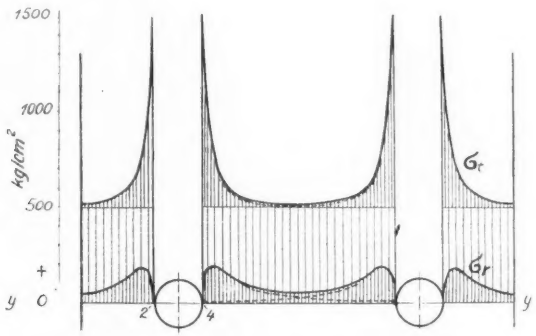

Abb. 10. Aussere Beanspruchung im Blech ($t=5\,d$)

FIG. 10.
Initial plate stress.

The overstress according to *Kirsch* is zero at Point 1; the resultant peak of the combined elastic expansion and simple side-thrust stresses, is 2,175 kg./cm.^{2} in compression, and 3,300 kg./cm.^{2} with the doubled side-thrust. The radial stresses, on the other hand, decrease very rapidly, progressively approaching the mean tensile plate stress of 500 kg./cm.^{2}, contrary to the tangential stresses tending to zero.

III. WIDELY-SPACED RIVETS ($t=5\,d$).

It will now be attempted to determine the influence of rivet pitch on the stresses in the plate between the rivet holes, repeating the calculations for double pitch ($t=5\,d$) without regarding the influence of side thrust.

Fig. 8 shows the influence of *elastic expansion*. While with a close pitch of $t=2.5\,d$, the overstress in the plate between two rivet holes is about 350 kg./cm.^{2}, with a wide pitch this falls to 80 kg./cm.^{2}. The peak stresses at the edge of the hole are not materially affected by the spacing.

Fig. 9 shows the influence of *side-thrust*. The example is calculated on the assumption that the initial unit stress on the plate is maintained at 500 kg./cm.^{2} both for close and wide spacing: $t=2.5\,d$ or $t=5.0\,d$; but since the total load $P=\sigma$, $f=500$. 9.1 increases proportionally to the area "f," the side-thrust for

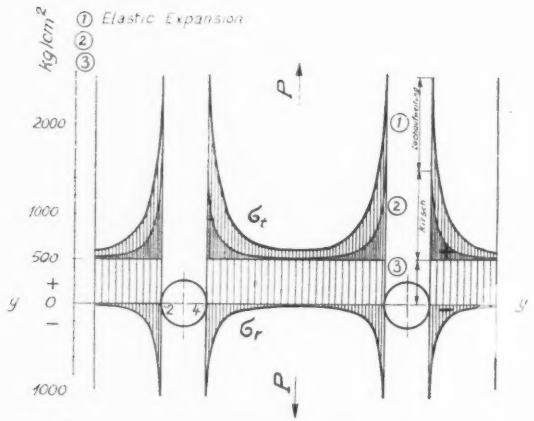

Abb. 11. Summenkurve σ_t und σ_r quer zur Kraftrichtung ($t = 5d$).

FIG. 11.

Curve of total stress transversely to direction of force.

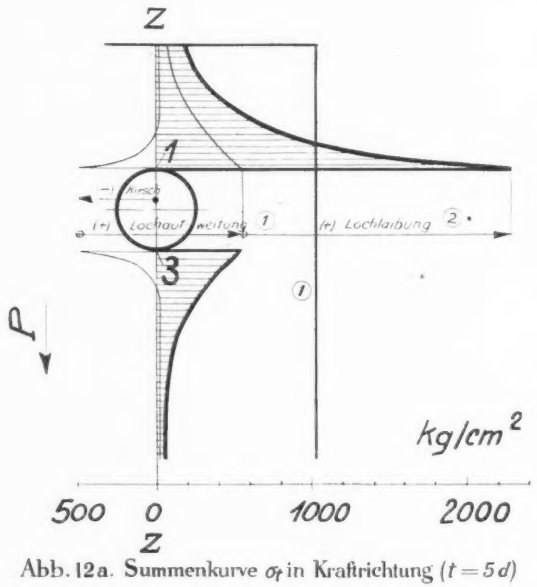

Abb. 12a. Summenkurve σ_t in Kraftrichtung ($t = 5d$)

FIG. 12a.

Curve of total stress in direction of force.

the same number of rivets will rise to 1,750 kg. cm.^{2}, which is no longer practically permissible. Since, as already stated, it is only intended to examine the influence of rivet spacing on the stresses in the plate between rivet holes, Fig. 9 has been calculated with the simple side-thrust only. The example essentially demonstrates that it is obviously impossible to vary the rivet spacing arbitrarily, but that there exists only one suitable spacing for optimum stresses in both directions.

The initial stresses in the plate are affected as follows:—

(*a*) *Transversely to the direction of force*:—Cross-section "$y-y$."

Fig. 10 shows that the influence of a neighbouring hole is already very slight. The stress peak at the edge of the hole has not materially decreased, but the overstress in the portion of the plate between the holes is still only 22 kg. cm.^{2}, while for a rivet spacing of $t=2.5\,d$ it was 120 kg. cm.^{2}.

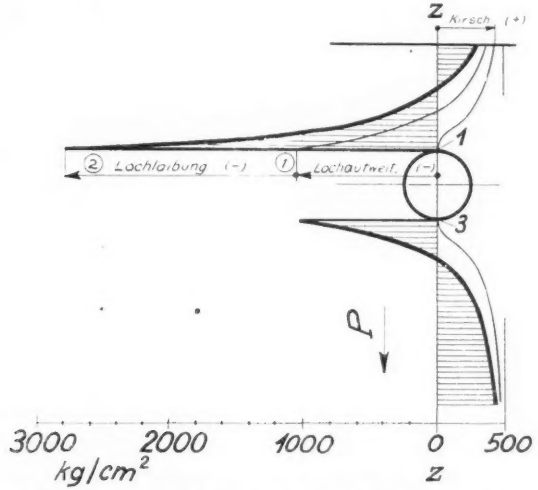

Abb. 12b. Summenkurve σ_r in Kraftrichtung ($t=5\,d$).

im Punkt 1 eine Resultante von 2800 kg/cm².

Zürich, Ingenieurbureau Dr. M. Koenig.

FIG. 12*b*.

Curve of total stress in direction of force.

(*b*) *In the direction of force*:—Points 1 and 3, cross-section "$z-z$."

The stress condition is the same as that represented in Fig. 5 for close-spaced rivets, the development of the stress values being identical.

The algebraic total stress curves show the mitigating effect of wider rivet spacing still more clearly.

(*a*) *Transversely to the direction of Force*:—Points 2 and 4, cress-section "$y-y$."

The peak stress at Point 4 has fallen from 2,633 kg./cm.^{2} for $t=2.5\,d$, to 2,566 kg./cm.^{2} for t . d 5.0 d. In the plate between the two rivet holes, the reduction is 900-600 = 300 kg./cm.^{2}.

At this cross-section, the influence of the radial stresses is less, the peak attaining only 1,050 kg./cm.² and very quickly tending to zero. The tangential stress again progressively approaches the initial plate stress of 500 kg./cm.². Only tangential stress need be considered.

(*b*) *In the direction of force*:—Points 1 and 3, cross-section "$z-z$."

Fig. 12*a* shows the great influence of unilateral concentration of the side thrust on the tangential stress at the edge of the hole. The overstress according to *Kirsch*, again has a damping effect. In other respects, the remarks to Fig. 7*a* apply.

Fig. 12*b* shows that the radial compressive stresses produce a total stress peak of 2,800 kg./cm.² at Point 1.

Appendix.

(3) Extract from "Theory of Elasticity in Relation to the Theory of Strength," Dr. Kirsch, Z.V.D.I., Vol. 42, No. 29, 16th July, 1898, pp. 798-799.

". . . For the analysis of such a case, assume a sheet of metal of infinite extent under uniform stress in every direction, provided with a circular hole. Then, the originally everywhere uniform stress distribution will become disturbed around the hole, the divergence attaining its maximum in the region bordering the hole. Even without calculation, it will be obvious that along any circle concentric to the hole, there will be a uniform peripheral stress σ_u, as well as a uniform radial stress σ_r normal thereto; which will be the principal stresses at the point in question. Furthermore, in accordance with Hooke's law, the stresses σ_u and σ_r must have the values:—

$$\sigma_u = p\left(1 + \frac{a^2}{r^2}\right), \quad \sigma_r = p\left(1 - \frac{a^2}{r^2}\right)$$

where p = stress in the intact plate.
r = distance of the stress point from the centre.
a = radius of the hole.

The sum of the two stresses is therefore, as before, everywhere equal to $2p$; at a little distance from the hole, the difference between the two components is slight: *e.g.*, for $r = 5a$, $\sigma_u = 1.04\,p$, $\sigma_r = 0.96\,p$; while at the edge of the hole, *i.e.*, with $r = a$, the values are $\sigma_u = 2\,p$, $\sigma_r = 0$. The rapid reduction in stress from the edge of the hole outwards, is shown by Fig. 4, in which lines

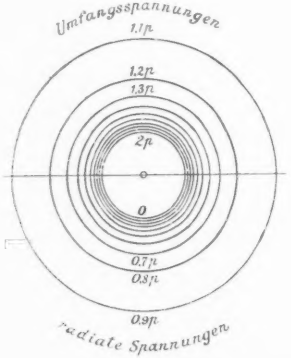

Fig. 4.

"*Umfangsspannungen*" = *circumferential stresses.*
"*Radiale spannungen*" = *radial stresses.*

of equal peripheral or radial stress are plotted for intervals of 0.1 p. Thus, if actually only the peak stress value were decisive, a plate pierced by a hole should rupture at the edge of the hole at the half of the ultimate stress of the unpierced plate; more exactly, in fact, the strength would be determined, not by the ratio $p : 2p$, but by that of $(m-1) : 2m$, since it is not the stress ratio, but that of the relative elongation which is decisive. In the present investigation, however, this difference was relatively of no importance, since no facilities were available for examining the actual behaviour of plates pierced with holes, under universally constant tensile stress.

Fig. 5.

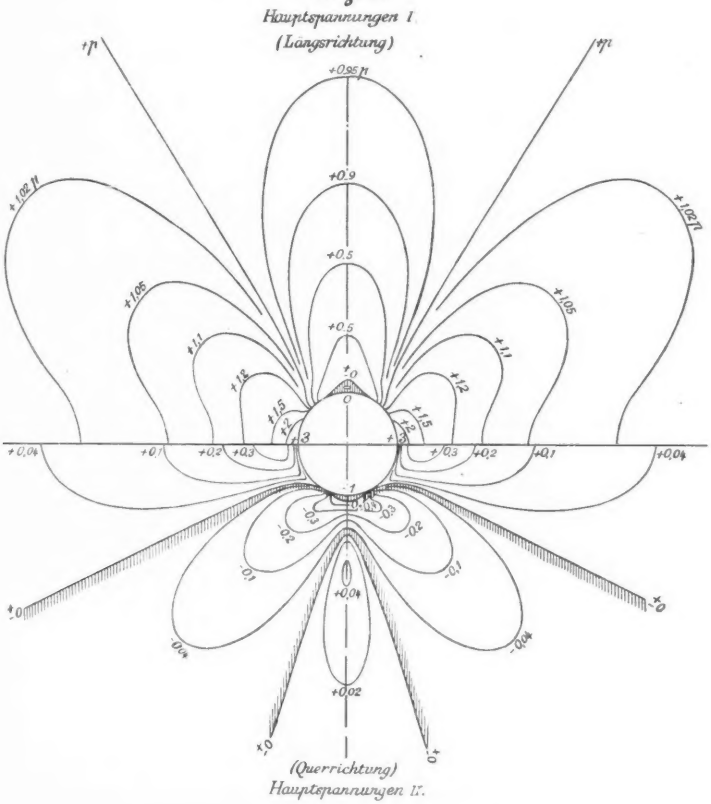

FIG. 5.

"*Hauptspannungen*" = *principal stresses.*
"*Längsrichtung*" = *longitudinal axis.*
"*Querrichtung*" = *transverse axis.*

It was only possible, instead of the universally-clamped plate, to test a plate clamped at one edge, and to determine the distribution of the stresses around a circular hole by preliminary calculation, for the case of applicability of Hooke's law. The requisite analysis proved so tedious that even partial recapitulation in the present paper proved impracticable. Only some of the results can be

quoted, according to which p_r and p_u are no longer equal for points on a circle of radius r concentric to the hole, but are still dependent on the angle θ made by the radius with the direction of action of the principal tensile stress, regarded as the longitudinal axis of the plate; furthermore, the components p_r and p_u are no longer principal stresses, since the accompanying shearing stress τ_{ru}, tending to change the right angle between the direction r and u, is generally not equal to zero. The equations of the decisive stresses are:—

$$\sigma_r = \tfrac{1}{2} p\left(1 - \frac{a^2}{r^2}\right) + \tfrac{1}{2} p\left(1 - \frac{a^2}{r^2}\right)\left(1 - \frac{3a^2}{r^2}\right)\cos 2\theta$$

$$\sigma_u = \tfrac{1}{2} p\left(1 + \frac{a^2}{r^2}\right) - \tfrac{1}{2} p\left(1 + \frac{3a^4}{r^4}\right)\cos 2\theta$$

$$\tau_{ru} = -\tfrac{1}{2} p\left(1 - \frac{a^2}{r^2}\right)\left(1 + \frac{3a^4}{r^2}\right)\sin 2\theta$$

which show, first of all, that for $r=a$, *i.e.*, at the edge of the hole, the radial and shearing stresses vanish, while the then remaining circumferential stress assumes either the minimum value $-p$ or maximum value $+3p$. For the region surrounding the hole, the stresses have been calculated for a number of points and plotted as lines of stress concentration, shown in Fig. 5. The regions of negative stress are indicated by shaded lines, and it will be observed that the two principal stresses I and II coincide with the longitudinal and transverse axes only at a considerable distance from the hole, while in the immediate vicinity they deviate considerably; an exception is made only by the points on the longitudinal and transverse axes themselves, where the direction of the principal stresses remains unchanged to the edge of the plate. The unpierced plate of course has equal principal stresses everywhere, *i.e.*, $\sigma_1 = p$ in the direction of tension, and $\sigma_2 = 0$ in the transverse direction; this indicates that the stresses in the pierced plate will increasingly agree in magnitude and direction, with increasing distance from the hole; the peak stress is $\sigma = 3p$, *i.e.*, three times as large as the longitudinal stress in the unpierced plate. If, consequently, the pierced plate is to behave completely elastically up to incipient rupture, fracture would commence always from the edges of the hole at the ends of a transverse diameter—and at a mean longitudinal stress of one-third the rupture strength of the unpierced plate. . . ."

THE INFLUENCE OF REYNOLDS NUMBER AT HIGH MACH NUMBERS.*

A. Ferri,

Atti di Guidonia, No. 67-69. Luftwissen, Vol. 10, No. 3, March, 1943, pp. 90-91.

The experiments were carried out in the high speed wind tunnel at Guidonia on three brass spheres of 40, 60 and 80 mm. diameter, supported on rear spindles and on two steel cylinders of 15 and 30 mm. diameter respectively, which passed through the air jet.

Both the total drag and pressure difference between the front stagnation point and a variable point at the rear were measured.

The pressure distribution on similar models which could be rotated and which were provided with pressure holes was also determined.

The following results were obtained:—

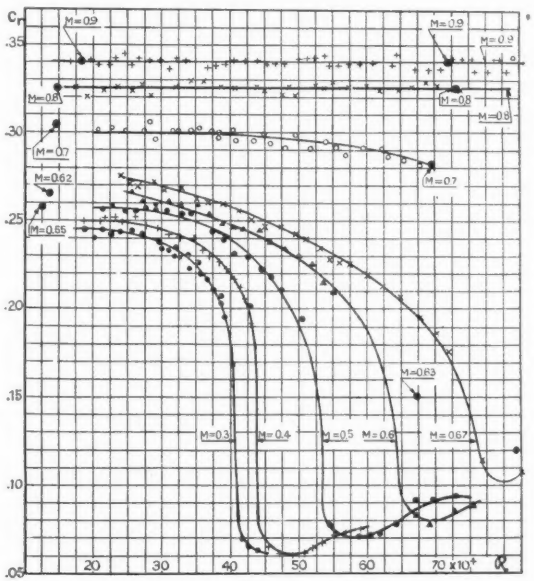

FIG. 1.

C_D as a function of Re with M as parmeter.

Resistance of Spheres. (*Re* range $20-80\times10^4$.)

For high Mach numbers (.8 and .9), C_D is independent of *Re* (Reynolds number) and equal to .325 and .340 respectively. At $M=.7$, C_D undergoes

* Printed by permission of the Ministry of Aircraft Production (R.T.P.).

a slight change with Re, the values ranging from .30 ($Re = 20 \times 10^4$) to .28 at $Re = 80 \times 10^4$.

For Mach numbers between .3 and .67, C_D, after a slight preliminary decrease with increase of Re undergoes a sudden drop at Re_{crit} to a minimum value, followed by a slight subsequent rise. This minimum value of C_D amounts to about 1/3 to 1/4 of the corresponding value at $Re = 20 \times 10^4$. Re_{crit} increases with M, as will be seen from the accompanying table.

The drag measurements were confirmed by pressure plotting and striation photographs of the field of flow.

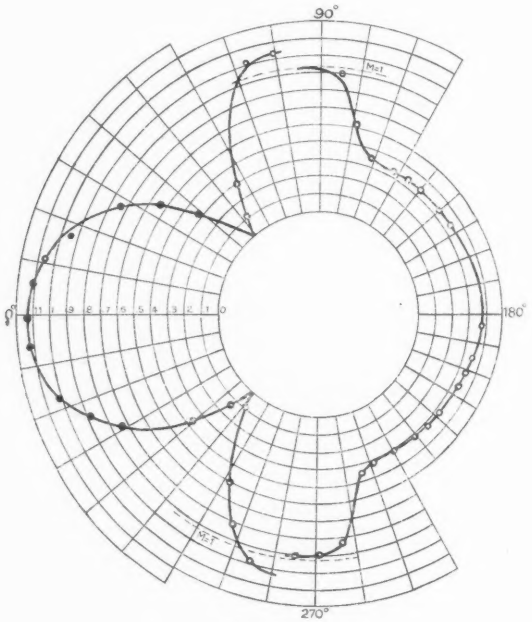

FIG. 2.

Pressure distribution on sphere

$Re = 70 \times 10^4$, $M = .7$.

c = positive pressure
o = suction
} *as fractions of* $\frac{1}{2}\rho V^2$.

Dotted circle corresponds to local $M = .1$.

At these points (azimuth 80° and 280° respectively) a shock wave is formed.

It appears that the critical drag at low Mach numbers up to $\sim .6$ is mainly due to the frontal dynamic head, the rear of the sphere being practically at static pressure (adhesion of flow). At high Mach numbers, however, a lateral shock wave is set up leading to a region of considerable negative pressure over the rear of the sphere and producing increased drag.

It is clear that under these conditions the sphere can no longer be used as a turbulence indicator.

It should be pointed out that these results apply to cylinders and spheres and that for aerofoils, C_D at $M > .7$ are likely to be a function of Re (thickness of boundary layer).

VARIATION OF RESISTANCE COEFFICIENT FOR SPHERE.

	C_D Mach Number						
$Re \times 10^4$	·3	·4	·5	·6	·67	·7	·8
20	.245	.250	.257	.270	.280	.300	·325
30	.237	.245	.255	.260	.270	.300	
40	.180	.220	.240	.250	.260	.300	
45	.06*	.07	.220	.240	.250	.298	
50	—	.06*	.190	.230	.240	.297	
55	—	.07	.075	.215	.230	.293	
60	—	.075	.070*	.190	.220	.290	
65	—	—	.080	.095	.205	.288	
70	—	—	.090	.080*	.185	.280	
75	—	—	.095	.090	.140	—	
80	—	—	—	—	.100*	—	
85	—	—	—	—	.110	—	·325

Constant.

* Critical Value.
— Not determined.

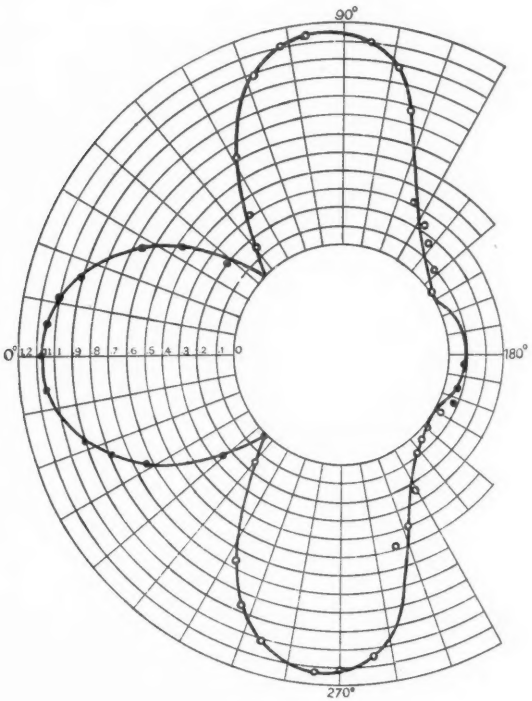

FIG. 3.

Pressure distribution on sphere
$Re = 64 \times 10^4$, $m = .55$.

It will be noted that the max. dynamic head (frontal stagnation point) follows very closely the theoretical value $q_M = q_0 (1 + \frac{1}{4}M^2)$ where q_0 = dynamic pressure at zero M (incompressible flow).

Comparison of Figs. 2 and 3 shows that at the lower Reynolds number $M=.55$ there exists only a small region of positive pressure ($p=.1q$) at the rear of the sphere. The flow is thus almost adherent and this accounts for the low drag ($C_D \sim .085$).

At $M=.7$ (Fig. 2), the lateral points of static pressure have moved slightly to the rear and a shock wave occurs at azimuth 80° and 280° respectively. This causes a collapse of the lateral suction field and its transfer to the rear of the sphere which is now subjected to a constant suction of $\sim .35q$.

C_D rises to .28 due to flow separation. As will be seen, C_D is independent of Re for $M=.8$ and .9 respectively. This independence is maintained for the supersonic range ($M=1.85$ and 2.13 respectively) C_D having a constant value of .6.

The lateral points of static pressure now travel back to almost the diametrel position and striation photographs show the presence of a shock wave in front of the sphere.

The increased pressure drop in the low pressure region corresponds to a higher curvature of the stream lines, similar to the case of thin aerofoils at speeds close to sonic values.

Under these conditions the sphere no longer acts as a turbulence indicator for the flow. In the case of aerofoils the change over from laminar to turbulent flow behind the first lateral shock wave may also depend on the thickness of the boundary layer and therefore on the Reynolds number.

REVIEWS.

Map Reading and Avigation.

By Richard M. Field and Harlan T. Stetson. Chapman and Hall, Ltd. 1943. 15/-.

This book, by two American authors, comes as a welcome addition to the small amount of material available to those who are studying map reading from an aeronautical standpoint. It is intended for the *ab initio* student and is planned for division into 26 class or laboratory periods of two hours each on map reading, and a similar period on " avigation " (that practical but ugly American synonym for air navigation). In the Appendix are a number of supplementary problems, together with specimen pages of the Air Almanac, the U.S. Hydrographic Office Tables, and other reference works for navigators. A bibliography and vocabulary of special terms are also included, and the book has a good index.

The layout is both practical and attractive, with its clear type and lavish illustrations. These for the most part show paired views of a landscape (actual or modelled), with the contour map made from it. From an English point of view it is perhaps a drawback that the examples and illustrations are all taken from the western hemisphere. Our own comparatively featureless and " muddled " countryside, for example, offers the pilot or map-reader no such crisp outlines as those of the contour agriculture and contour ploughing shown in Figs. 15 and 16. Some excellent diagrams illustrating the different types of map projection are contained in the second half of the book.

America Fledges Wings. The History of the Daniel Guggenheim Fund for the Promotion of Aeronautics.

R. M. Cleveland. Pitman Publishing Corporation, New York and Chicago. 1943. $4.50.

The name of Guggenheim will ever remain one of high honour in the history of aeronautics. To no one man, indeed, has the " promotion of aeronautics " owed so much, as it has to Daniel Guggenheim. This is the story which began in 1925 when Harry F. Guggenheim, an enthusiast for aviation, if ever there was one, talked to his father. Harry Guggenheim's immediate object was to raise $500,000 to start aeronautical education at New York University. The conversation ended with Daniel Guggenheim subscribing the whole sum himself and so founding the Daniel Guggenheim School of Aeronautics at the University.

But Daniel and Harry Guggenheim had that rare insight which is given to the few. They saw that the aeroplane would, ultimately, bring peace to the world, despite its obvious uses for war, and they decided to devote the whole of their energies to putting aviation on the map of the world, and making the world air-minded.

In January, 1926, Daniel Guggenheim wrote to Mr. Herbert Hoover, then Secretary of Commerce in the United States Government, offering to establish the Daniel Guggenheim Fund for the Promotion of Aeronautics with a sum of $2,500,000. He outlined that the broad purposes of the fund would be (1) to promote aeronautical education both in institutions of learning and among the general public; (2) to assist the extension of fundamental aeronautical science; (3) to assist in the development of commercial aircraft and aircraft equipment; and (4) to further the application of aircraft in business, industry and other economic and social activities of the nation.

Mr. Hoover, backed by the President, Mr. Coolidge, agreed to help this most generous proposition, which was governed by a Board of Trustees of eminent men in the Government and aviation, with Harry Guggenheim as its President. Almost immediately following the announcement of the fund, Harry Guggenheim and Admiral Cone sailed for Europe to make a tour of the principal countries to see how they could promote the advancement of aeronautics.

Their first visit was to the Royal Aeronautical Society in 1926, and in the August of that year the Fund notified the Society that its first grant was being made to them of £1,000 for the year 1927 for two purposes: (1) Supervising the collection and dissemination of important technical information not otherwise widely disseminated, and (2) assisting the Society in maintaining a permanent secretary in order more easily to continue its splendid contributions to the aeronautical science of the world.

Further grants of £1,000 were made for the years 1928 and 1929 and a final grant of £5,000 in 1930.

These grants were invaluable. They enabled the Society to expand its activities in all directions, increased its prestige, and placed the Society on a self-supporting basis.

Naturally attention has been drawn to the immense help the Fund gave to the Society at a very critical period in its history, but it is only by reading this account that the full and most remarkable story of the work of the Fund, its world-wide influence, and the astonishing effect it had on aviation everywhere, can be appreciated.

It is gratifying to know that in so many ways, particularly in the field of aeronautical education and research, the name of Guggenheim will be for ever remembered for remarkable foresight and great generosity.

A Bibliography of Aviation Medicine.

E. C. Hoff and J. F. Fulton. C. C. Thomas, Baltimore. 1942.

This volume has been prepared for the Committee on Aviation Medicine, of the National Research Council, acting for the Committee on Medical Research Office of Scientific Research and Development, Washington.

To quote from the preface: " The performance of modern combat aeroplanes in range, ceiling, and manœuvrability has so seriously taxed the human element that a new field of study has arisen which, for want of a better term, has been designated ' aviation medicine '."

The most astonishing thing about this bibliography is the great amount of literature which has already been devoted to the subject. There are close on six thousand references, covering every aspect from the History and General Aspects of Aviation Medicine, to Selection and Assessment of Efficiency of Flight Personnel, from Aviation and Public Health to such special problems as Parachute Jumping.

A most thorough search has been made of all likely sources of information and the result is a bibliography which will be absolutely invaluable to all those who wish to enter this rapidly growing branch of medicine. There is an excellent index of authors and subjects which add to the value of a work upon which the compilers are to be most heartily congratulated.

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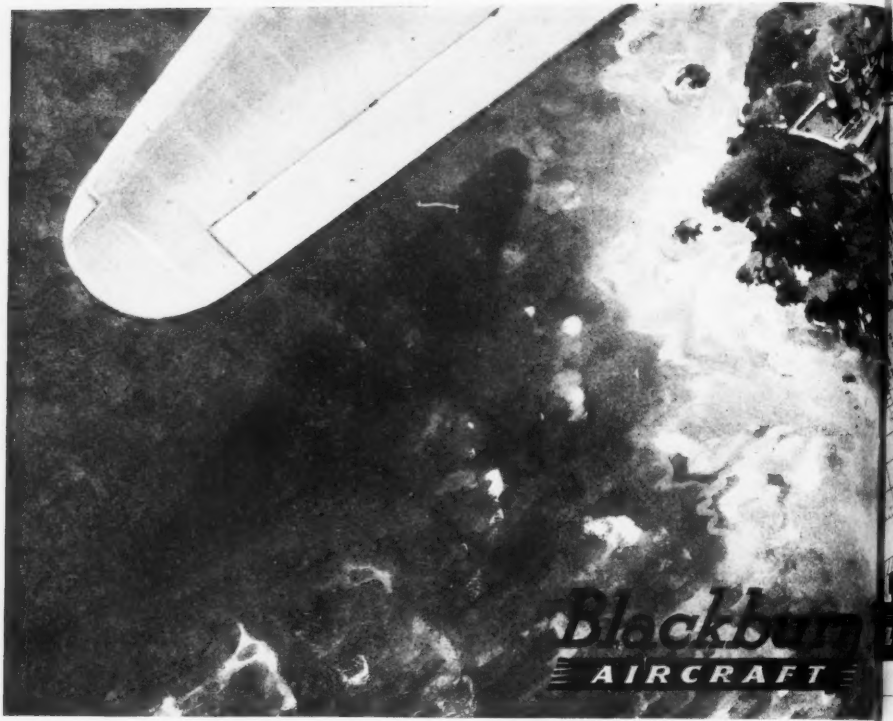

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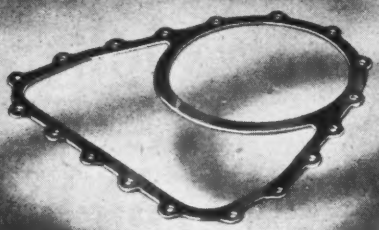

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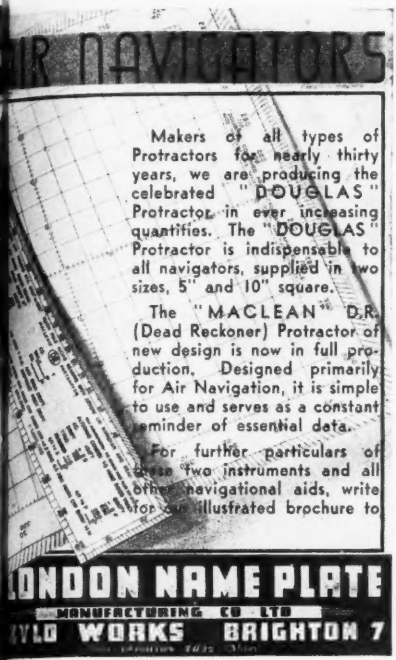

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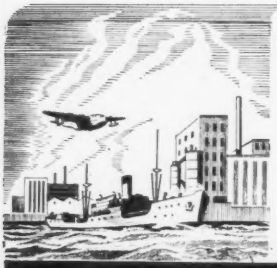

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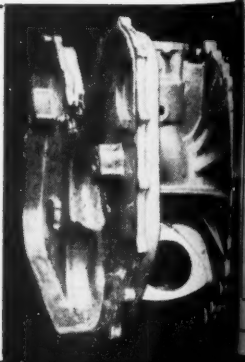

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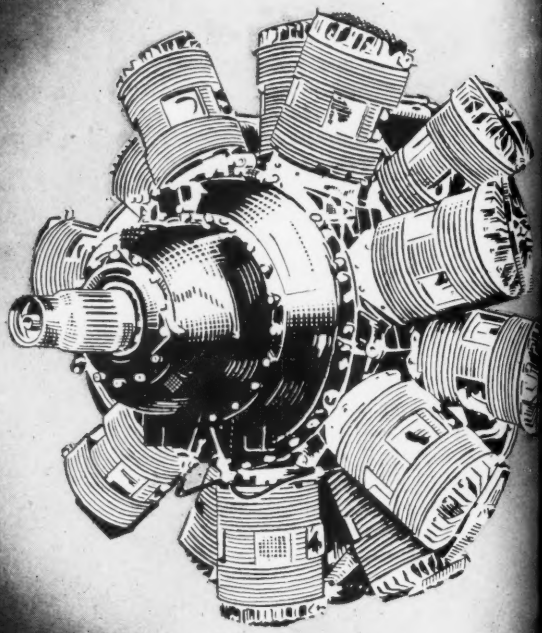

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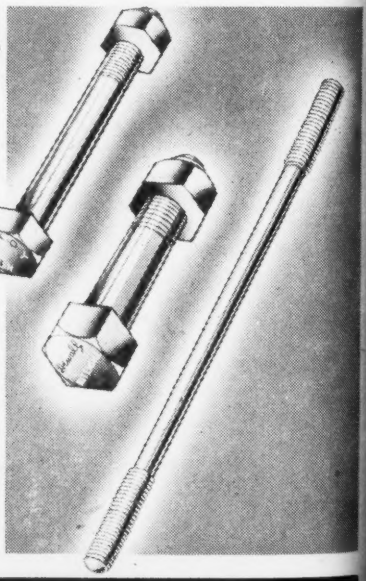

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